Fast Vector Processing Language

Programming Languages and Translators
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Topics Covered

- Language overview
- Tutorial
- Example program
- Architectural design
- Compiler implementation and features
- Testing
- Results
- Conclusion

Language Overview

- Computation of vectors like primitive types
- C like syntax and semantics
- Easy programming and fast execution
- Transparent and efficient utilization of SIMD instructions for computing at higher speeds
- SIMD instructions in x86 are called SSE and operates on 128 bits of data
- Data Parallelism is the goal of FVPL

Tutorial

- Basic data types, language constructs, types of operators and expressions, scopes are similar to the C programming language
- Consider the following program to add a vector to itself, assign the result to another vector and then display the result

```
int main()
{
  int a[10], b[10];
  a = 5;
  b = a + a;
  print(b);
}
```

Tutorial (cont..)

- To execute the program, use the command

  $ ARGS="add_vector.fvpl" make exec; ./a.out

- The generated output would be:

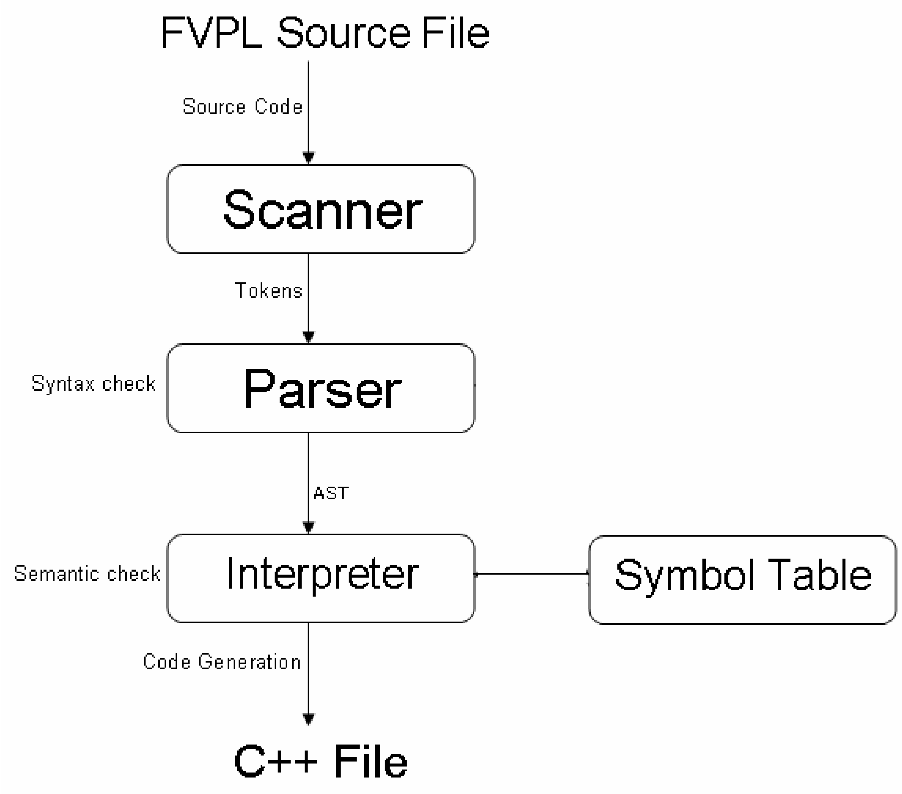
  10
  10
  10
  10
  10
  10
  10
  10
  10
  10

Example Program

- Program demonstrating vector operations

```
int main(){
        int a[10], b[10], c[10];
        fread_int("aFile", a, 10);
        fread_int("bFile", b, 10);
        c = a&b;
        b = c+a;
        fwrite_int("cOut", c, 10);
        fwrite_int("bOut", b, 10);
}
```

Architecture



Architecture (cont..)

- Lexer: Scans the FVPL source code to generate tokens based on a set of rules
- Parser: Parses input sequence of tokens from lexer to determine if the program is syntactically correct. Generates the AST
- Interpreter: Walks the AST and checks if program is semantically correct. Populates the symbol table
- Code generation: Translation of vector operations to function calls. Optimized functions reside in C++ stub code. Generated C++ code passed to the g++ compiler

Compiler Implementation

- OCaml Lex
- Ocaml Yacc
- Eclipse (with OCalIDE)
- CVS (cvs.sourceforge.net)
- Shell script for testing

Compiler Features

- Generates C++ code from the source FVPL code
- Optimized routines to handle vector operations as part of stub code
- Stub code added as library to the generated C++ code
- Generated code compiled with g++
- Modular implementation

Testing

- Regression testing one at all stages using a shell script
- Positive and negative test cases written as part of the test suite
- Positive tests: Ensures generated C++ code and output is consistent for any valid input
- Negative tests: Ensures that the compiler catches all error conditions and provides the programmer with appropriate error messages

Testing (cont..)

- Shell script *testscript.sh* automates the testing process
- Runs both the positive and negative test cases when invoked by the *make test* command
- Excerpt of the generated output

------------ Testing FVPL success cases ------------
tests/success/test-comments.input --------------- SUCCESS
tests/success/test-continue-break.input --------------- SUCCESS
tests/success/test-fibonacci.input --------------- SUCCESS
tests/success/test-file-input.input --------------- SUCCESS
tests/success/test-for.input --------------- SUCCESS
…
…
------------ Testing FVPL failure cases ------------
Fatal error: exception Failure("Cannot have more than one main function")
tests/failure/test-2mains.input --------------- FAIL
Fatal error: exception Failure("number of params different 2")
tests/failure/test-func1.input --------------- FAIL
Fatal error: exception Failure("Type of arguments not matching defined function3")
tests/failure/test-func2.input --------------- FAIL
…
…

Source Code Statistics

scanner.mll	76
parser.mly	156
ast.mli	76
interpret.ml	358
symbol.ml	140
fvpl.ml	10
stub.h	867
stub-print.h	131
Makefile	38
testscript.sh	39
Total	1852

Test Case Statistics

Positive Test Cases	
Number of test cases	40
Number of lines in input files	505
Number of lines in output files	743
Output Test Cases	
Number of test cases	20
Number of lines in input files	123

Results

- FVPL versus GCC compiler
  - ***Time Taken by C++ code to add brightness to 5 MB image=416.994ms***
  - ***Time Taken by FVPL to add brightness to 5 MB image= 212.091ms***
  - ***Time Taken by C++ code to mask and multiply pixel(5 MB image)=568.638ms***
  - ***Time Taken by FVPL code to mask and multiply pixel(5 MB image)=259.936ms***
- FVPL shows 2X speed up in our tests
- Performance limited due to redundant data copy

Conclusion

- Using FVPL makes vector operations very simple
- Fast vector processing is important in Image Processing, Matrix operations, String matching and Cryptography
- FVPL does not exploit the full potential of SSE.

Conclusion (cont..)

- Useful enhancements to FVPL
  - 16 byte alignment
  - In-place and not in-place operations
  - Multi-dimensional array support
  - Operation on partial array
  - Intra-procedural data redundancy check
- FVPL leading the way for future architectures like Larrabee